Cognitive Radios

The role of cognitive radios in public safety and incident response.

Where do we place the intelligence?

1. User
2. Subscriber equipment
3. System design
4. System intelligence or management
5. Operational planning
6. ?

For today's discussion, let's assume within the subscriber unit. Let's also assume the difference between a software defined radio and a cognitive radio is the radio's awareness of its environment.

1st Question

1. What is a cognitive radio?

Definition of Cognitive

1. Awareness with perception, reasoning and judgment, intuition, and memory; The mental process by which knowledge is acquired.
2. The term cognition (Latin: cognoscere, "to know") is used in several loosely related ways to refer to a faculty for the human-like processing of information, applying knowledge and changing preferences. ...
3. Relating to or involving the act or process of knowing, including both awareness and judgment. Cognition is characterized by the following: attention, language/symbols, judgment, reasoning, memory, problem-solving.

Cognitive Radios

Two primary types of cognitive radios:

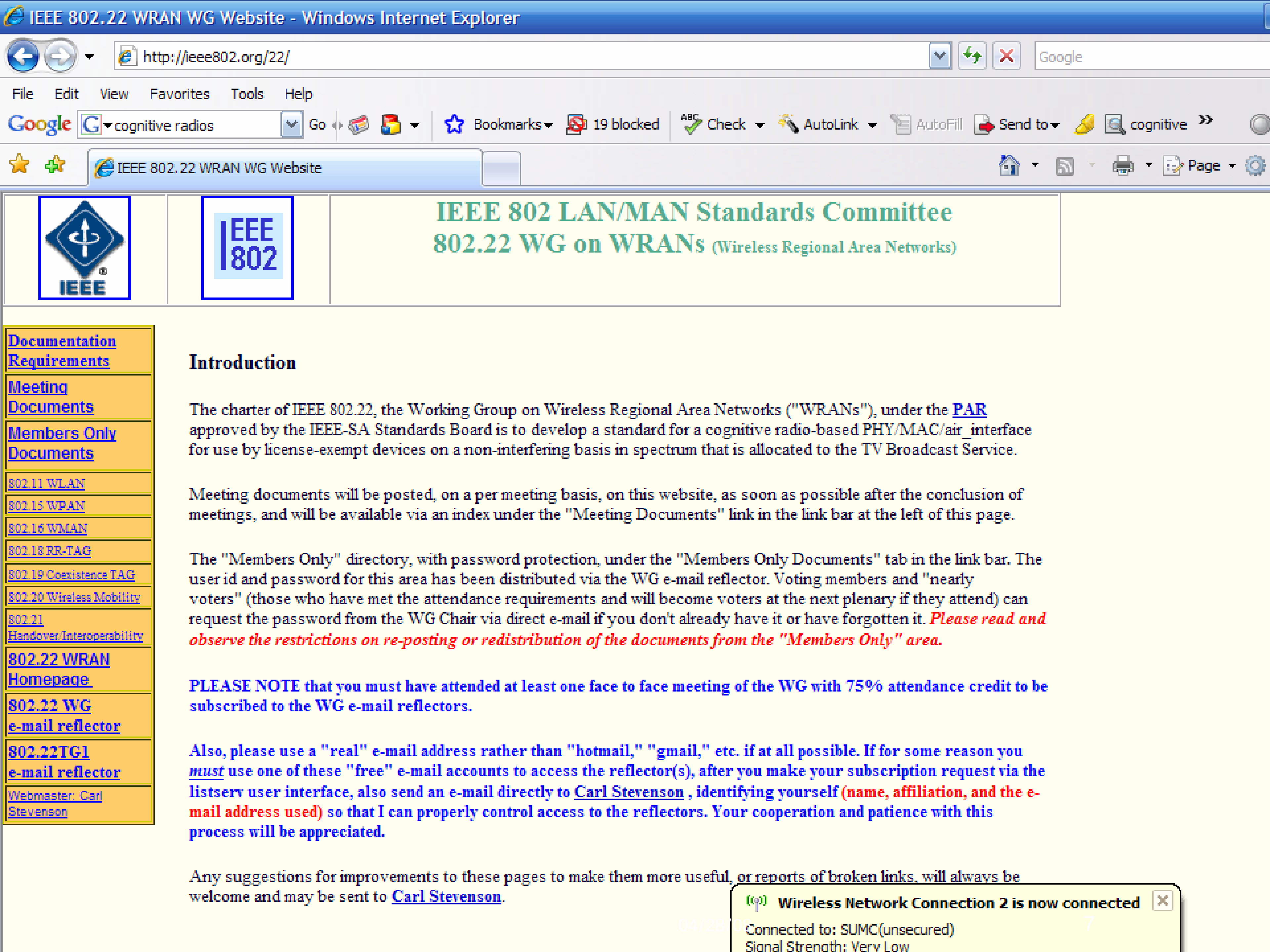
1. **Full Cognitive Radio** (“Mitola Radio"): in which every possible parameter observable by a wireless node or network is taken into account.
2. **Spectrum Sensing Cognitive Radio**: in which only the radio frequency spectrum is considered.

Wikipedia

Let’s Consider Two Types

- **Licensed Band Cognitive Radio**: in which cognitive radio is capable of using bands assigned to licensed users, apart from unlicensed bands, such as U-NII band or ISM band. The IEEE 802.22 working group is developing a standard for wireless regional area network (WRAN) which will operate in unused television channels.
- **Unlicensed Band Cognitive Radio**: which can only utilize unlicensed parts of radio frequency spectrum. One such system is described in the IEEE 802.15 Task group 2 specification, which focuses on the coexistence of IEEE 802.11 and Bluetooth.

Wikipedia



IEEE 802 LAN/MAN Standards Committee
802.22 WG on WRANs (Wireless Regional Area Networks)

- Documentation Requirements
- Meeting Documents
- Members Only Documents
- 802.11 WLAN
- 802.15 WPAN
- 802.16 WMAN
- 802.18 RR-TAG
- 802.19 Coexistence TAG
- 802.20 Wireless Mobility
- 802.21 Handover/Interoperability
- 802.22 WRAN Homepage
- 802.22 WG e-mail reflector
- 802.22TG1 e-mail reflector
- Webmaster: Carl Stevenson

Introduction

The charter of IEEE 802.22, the Working Group on Wireless Regional Area Networks ("WRANs"), under the PAR approved by the IEEE-SA Standards Board is to develop a standard for a cognitive radio-based PHY/MAC/air_interface for use by license-exempt devices on a non-interfering basis in spectrum that is allocated to the TV Broadcast Service.

Meeting documents will be posted, on a per meeting basis, on this website, as soon as possible after the conclusion of meetings, and will be available via an index under the "Meeting Documents" link in the link bar at the left of this page.

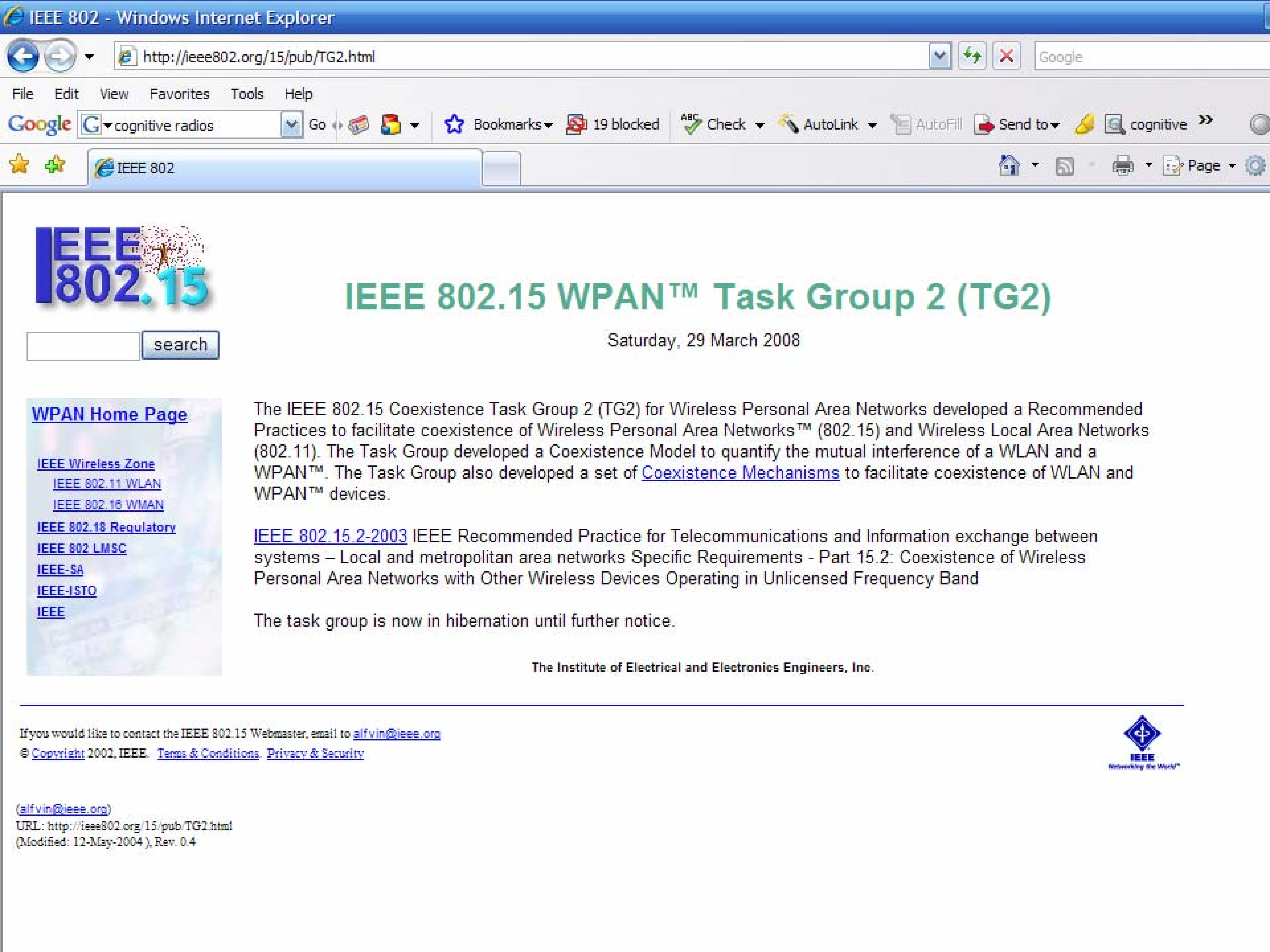
The "Members Only" directory, with password protection, under the "Members Only Documents" tab in the link bar. The user id and password for this area has been distributed via the WG e-mail reflector. Voting members and "nearly voters" (those who have met the attendance requirements and will become voters at the next plenary if they attend) can request the password from the WG Chair via direct e-mail if you don't already have it or have forgotten it. *Please read and observe the restrictions on re-posting or redistribution of the documents from the "Members Only" area.*

PLEASE NOTE that you must have attended at least one face to face meeting of the WG with 75% attendance credit to be subscribed to the WG e-mail reflectors.

Also, please use a "real" e-mail address rather than "hotmail," "gmail," etc. if at all possible. If for some reason you *must* use one of these "free" e-mail accounts to access the reflector(s), after you make your subscription request via the listserv user interface, also send an e-mail directly to Carl Stevenson , identifying yourself (name, affiliation, and the e-mail address used) so that I can properly control access to the reflectors. Your cooperation and patience with this process will be appreciated.

Any suggestions for improvements to these pages to make them more useful, or reports of broken links, will always be welcome and may be sent to Carl Stevenson.

Wireless Network Connection 2 is now connected
Connected to: SUMC(unsecured)
Signal Strength: Very Low



IEEE 802.15 WPAN™ Task Group 2 (TG2)

Saturday, 29 March 2008

WPAN Home Page

- IEEE Wireless Zone
  - IEEE 802.11 WLAN
  - IEEE 802.16 WMAN
- IEEE 802.18 Regulatory
- IEEE 802 LMSC
- IEEE-SA
- IEEE-ISTO
- IEEE

The IEEE 802.15 Coexistence Task Group 2 (TG2) for Wireless Personal Area Networks developed a Recommended Practices to facilitate coexistence of Wireless Personal Area Networks™ (802.15) and Wireless Local Area Networks (802.11). The Task Group developed a Coexistence Model to quantify the mutual interference of a WLAN and a WPAN™. The Task Group also developed a set of Coexistence Mechanisms to facilitate coexistence of WLAN and WPAN™ devices.

IEEE 802.15.2-2003 IEEE Recommended Practice for Telecommunications and Information exchange between systems – Local and metropolitan area networks Specific Requirements - Part 15.2: Coexistence of Wireless Personal Area Networks with Other Wireless Devices Operating in Unlicensed Frequency Band

The task group is now in hibernation until further notice.

The Institute of Electrical and Electronics Engineers, Inc.

If you would like to contact the IEEE 802.15 Webmaster, email to alfvin@ieee.org

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(alfvin@ieee.org)
URL: http://ieee802.org/15/pub/TG2.html
(Modified: 12-May-2004), Rev. 0.4

2nd Question

1. What is a cognitive radio?
2. Why do we need a cognitive radio?

Basis for Cognitive Radios

1. According to the FCC variation in the utilization of the assigned spectrum range from 15% to 85%.
2. Spectrum is a finite resource
3. Supply and demand means that the value of vacant spectrum is increasing.
4. Current frustration and competition for frequencies is gaining public attention
5. The current frequency allocations for public safety do not meet needs.

Assertion: we need more spectrum or a means of using existing spectrum more efficiently.

3rd Question

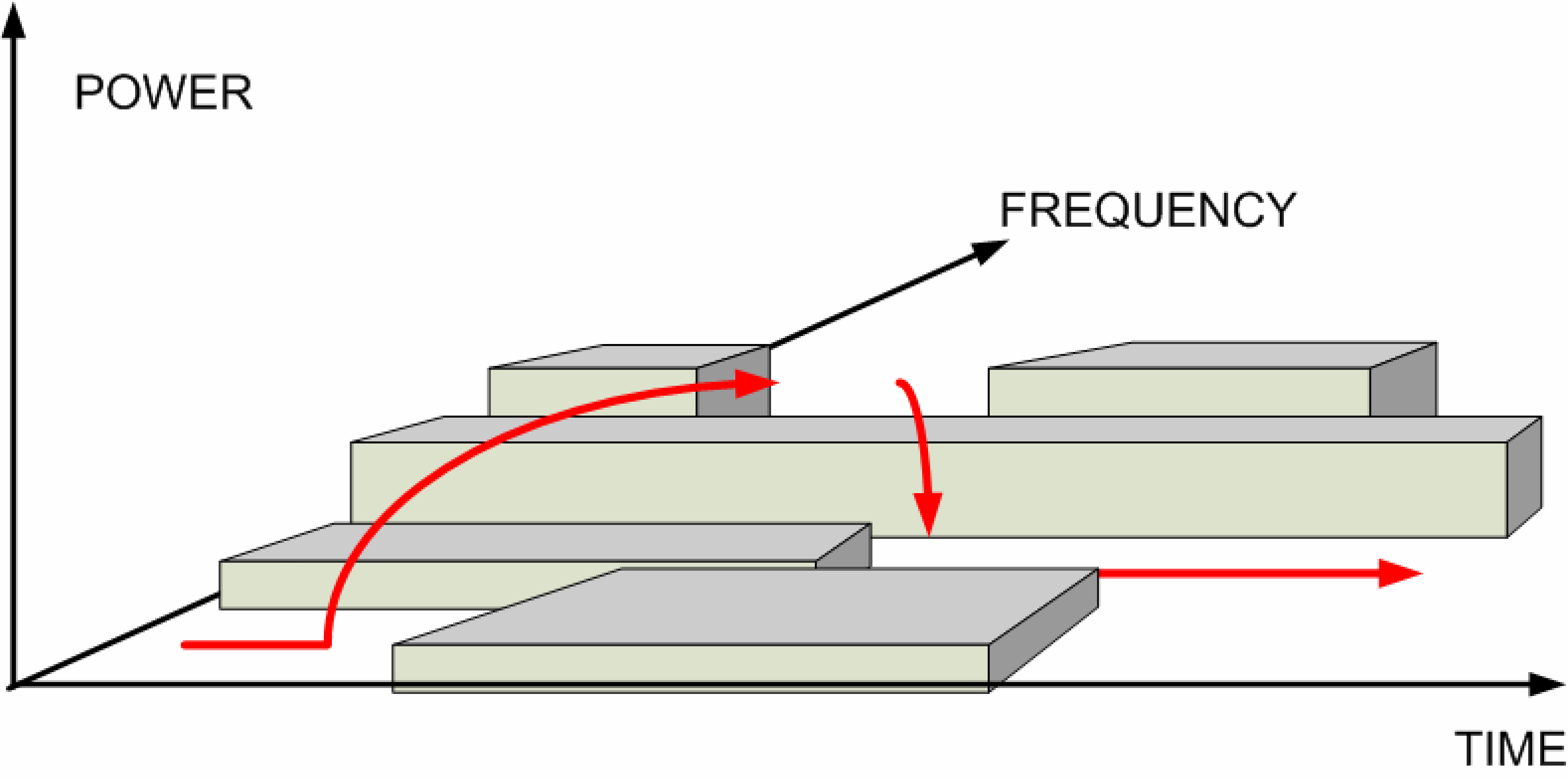
1. What is a cognitive radio?
2. Why do we need a cognitive radio?
3. Where do we place the intelligence?

Cognitive Radio Functions

- **Spectrum Sensing:** detecting temporarily vacant spectrum and sharing it without harmful interference to other users.
- **Spectrum Management:** capturing the best available spectrum to meet user needs.
- **Spectrum Mobility:** being able to move between vacant spectrum locations with user interruption.
- **Spectrum Sharing:** providing fair spectrum access.

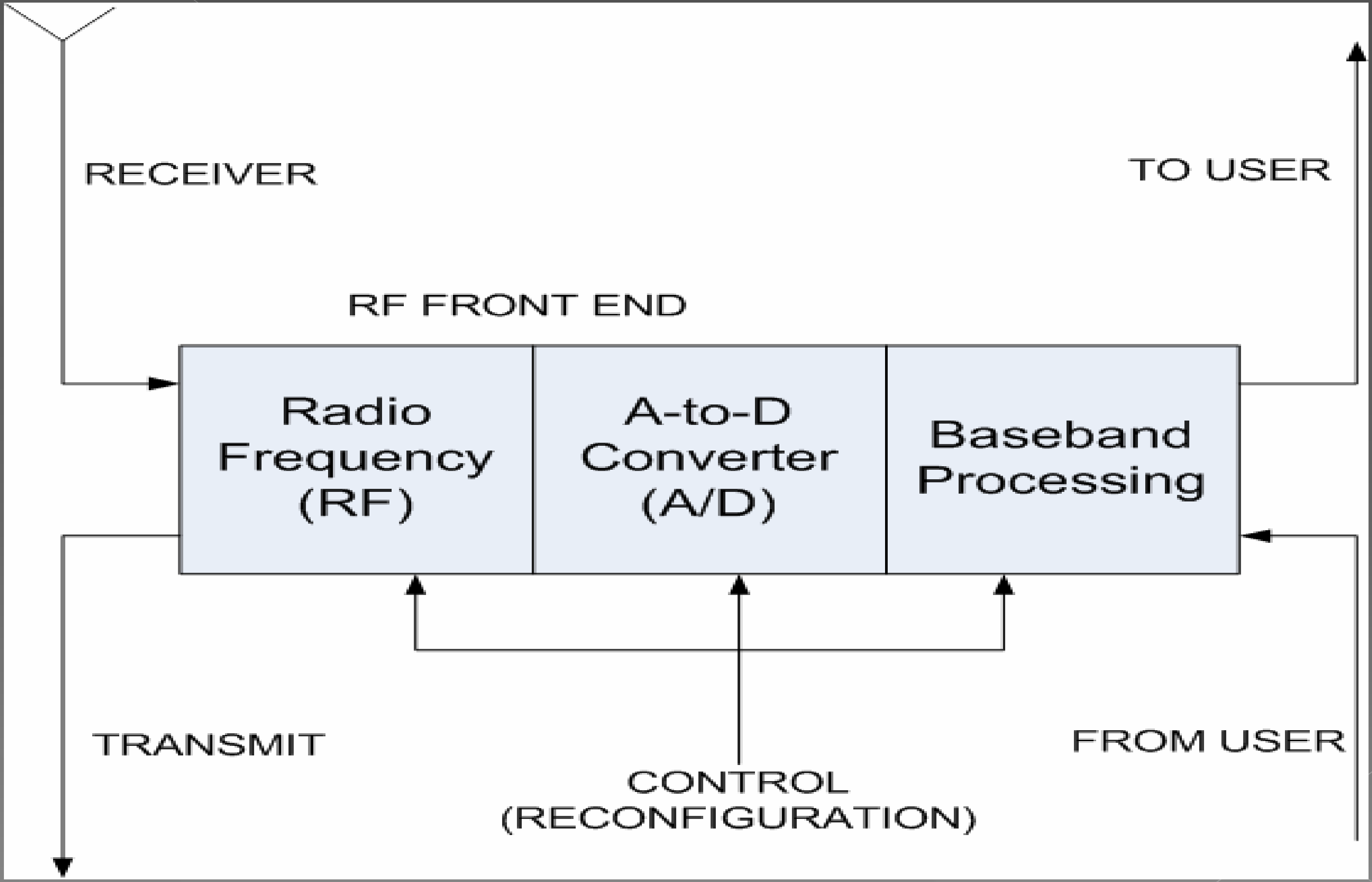
A “Cognitive Radio” is a radio that can change its transmitter parameters based on interaction with the environment which it operates. [FCC Docket No 03-222 Notice of Proposed Rule Making and Order; December 2003]

Spectrum Holes Concept



Cognitive radio behavior requires cognitive capability and reconfiguration capability.

Cognitive Radio Architecture



RECEIVER

TO USER

RF FRONT END

Radio Frequency (RF)

A-to-D Converter (A/D)

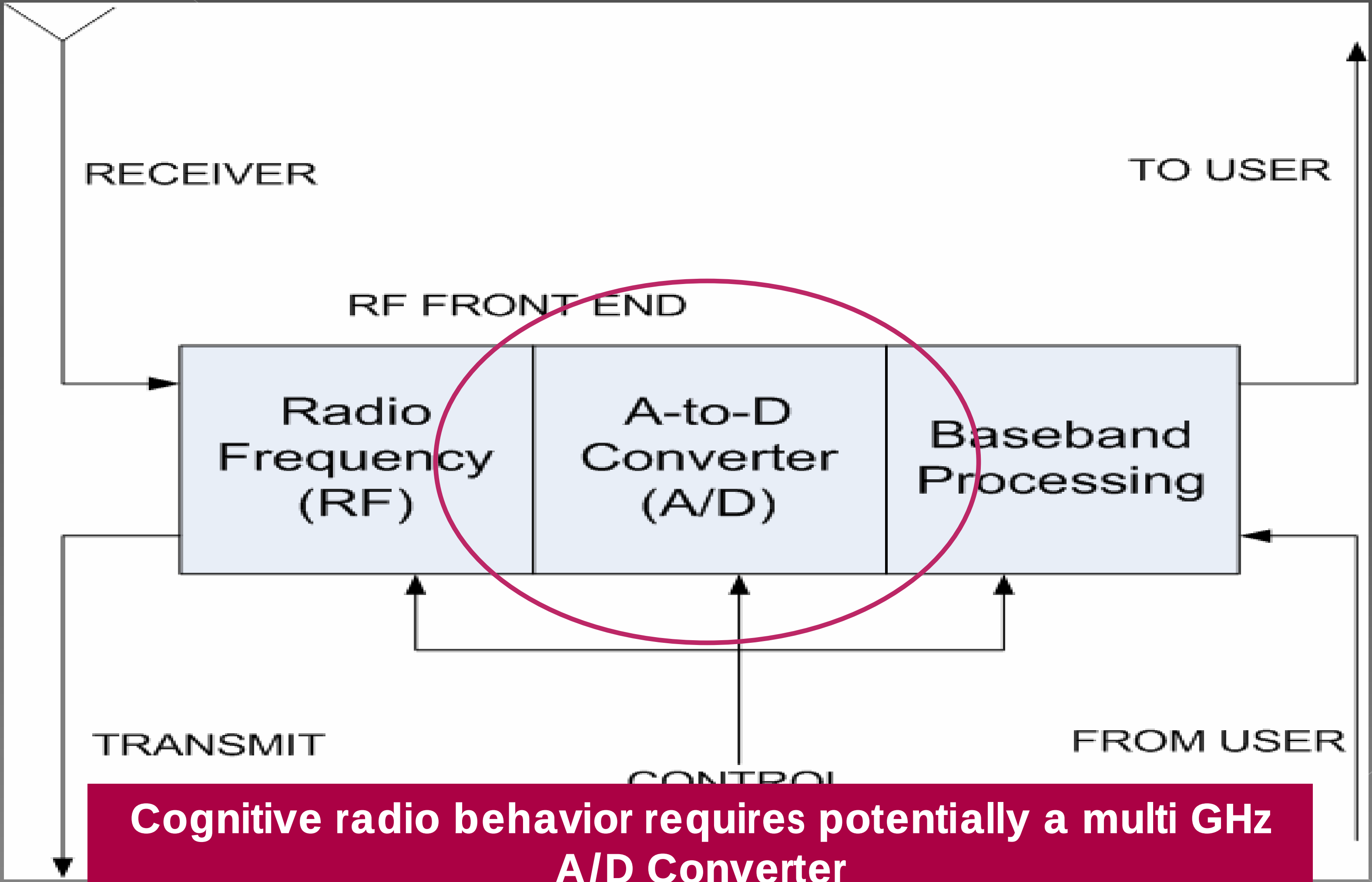
Baseband Processing

TRANSMIT

FROM USER

CONTROL (RECONFIGURATION)

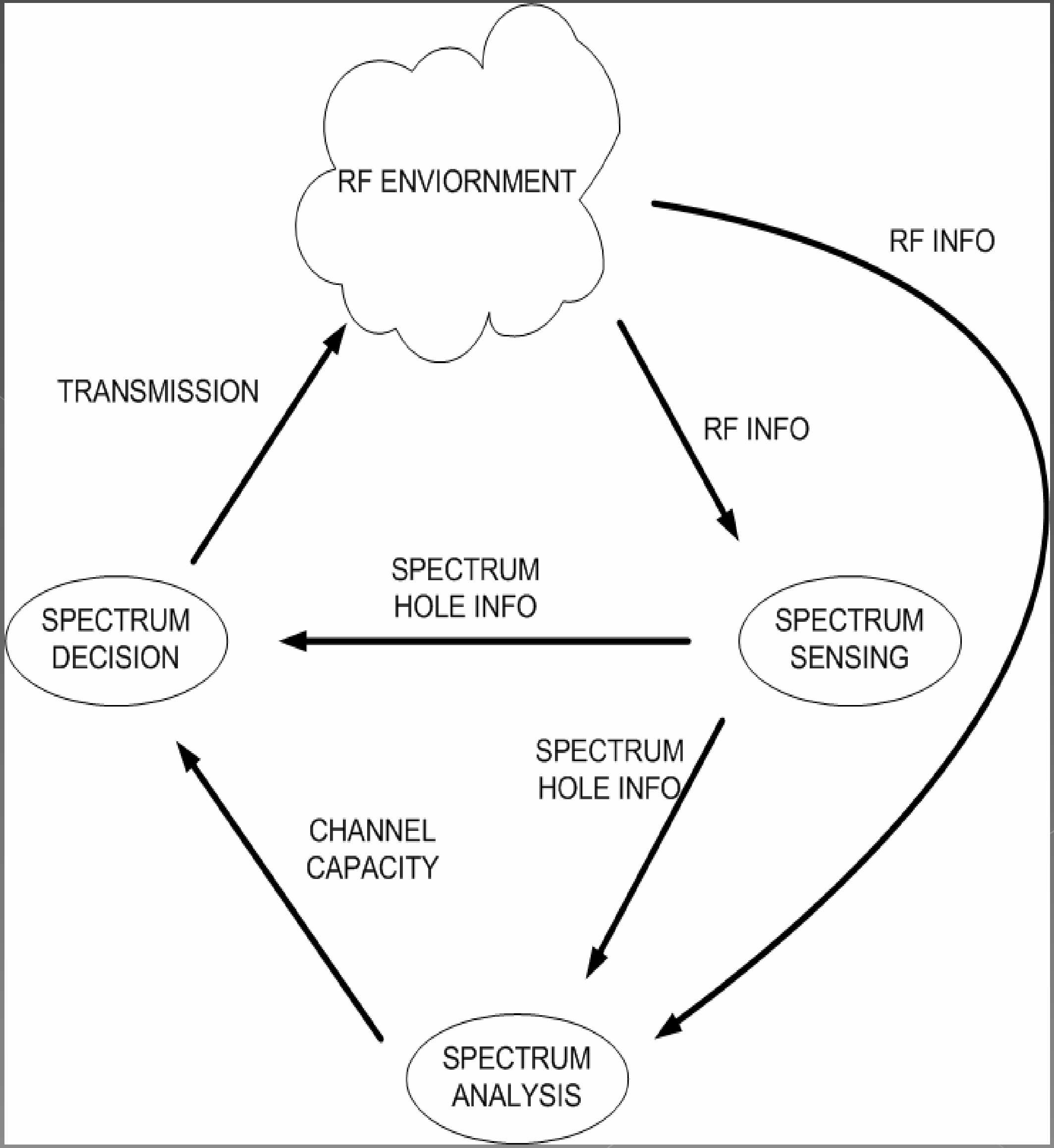
Cognitive Radio Architecture Issue



Cognitive radio behavior requires potentially a multi GHz A/D Converter

Cognitive Capability or Cycle

1. Spectrum sensing
2. Spectrum analysis
3. Spectrum decision

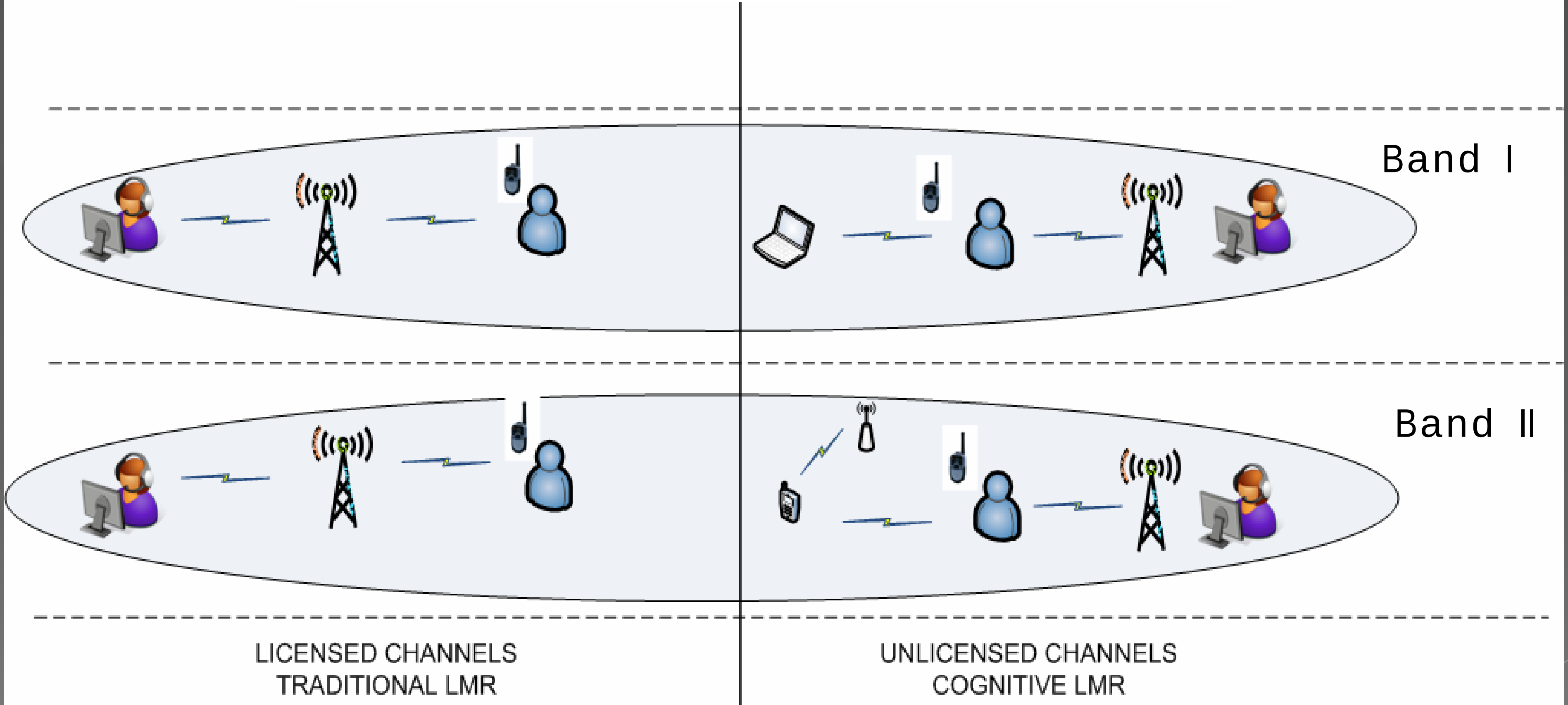


Reconfiguration Capability

Cognitive radio reconfiguration parameters include:

1. Operating frequency
2. Modulation
3. Transmission power
4. Communication technology

Cognitive System Example

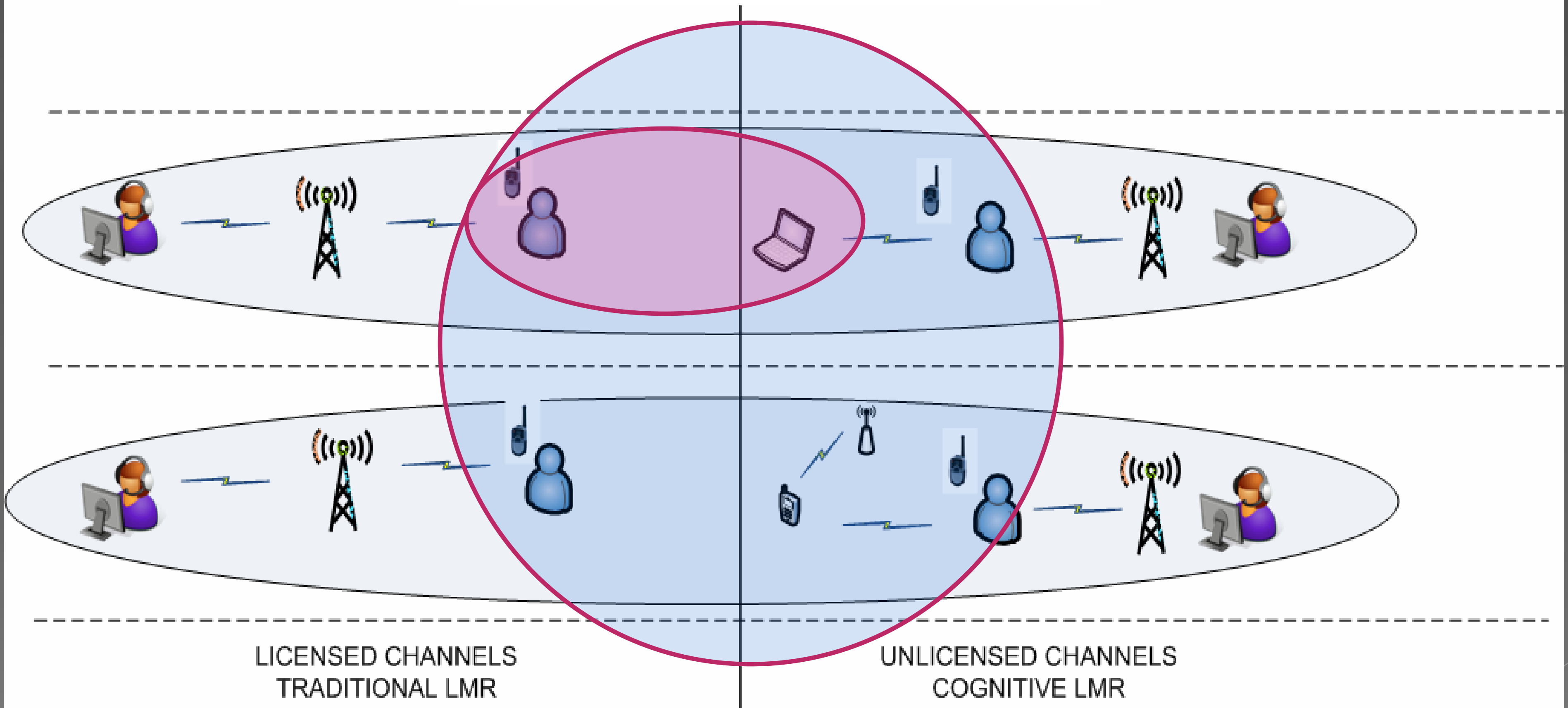


Cognitive radio access types: network access, ad hoc access, primary network access

4th Question

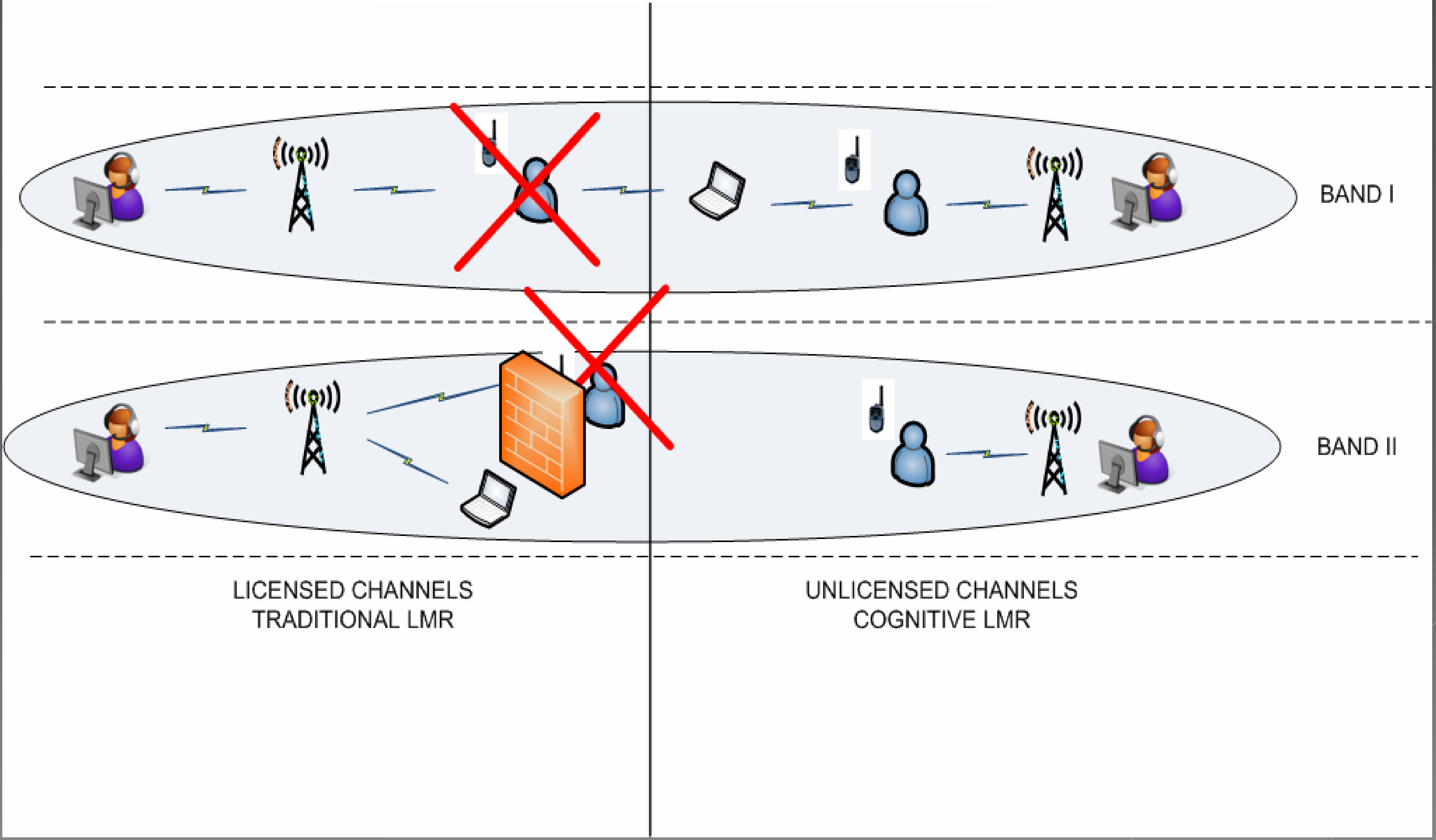
1. What is a cognitive radio?
2. Why do we need a cognitive radio?
3. Where do we place the intelligence?
4. How do we gain intelligence?

Spectrum Sensing



Primary spectrum sensing methods: transmitter detection (non-cooperative), cooperative, interference-based

System Challenges



Spectrum Analysis

Spectrum analysis or channel capacity parameters include:

1. Interference characteristics
2. Path loss
3. Wireless link errors
4. Link layer delay
5. Holding time
6. Geographic position

Spectrum Mobility

Consideration for spectrum mobility

1. Spectrum handoff
2. Infrastructure routing
3. Service interruption
4. Higher layer protocols
5. Network convergence time
6. Common control channel

5th Question

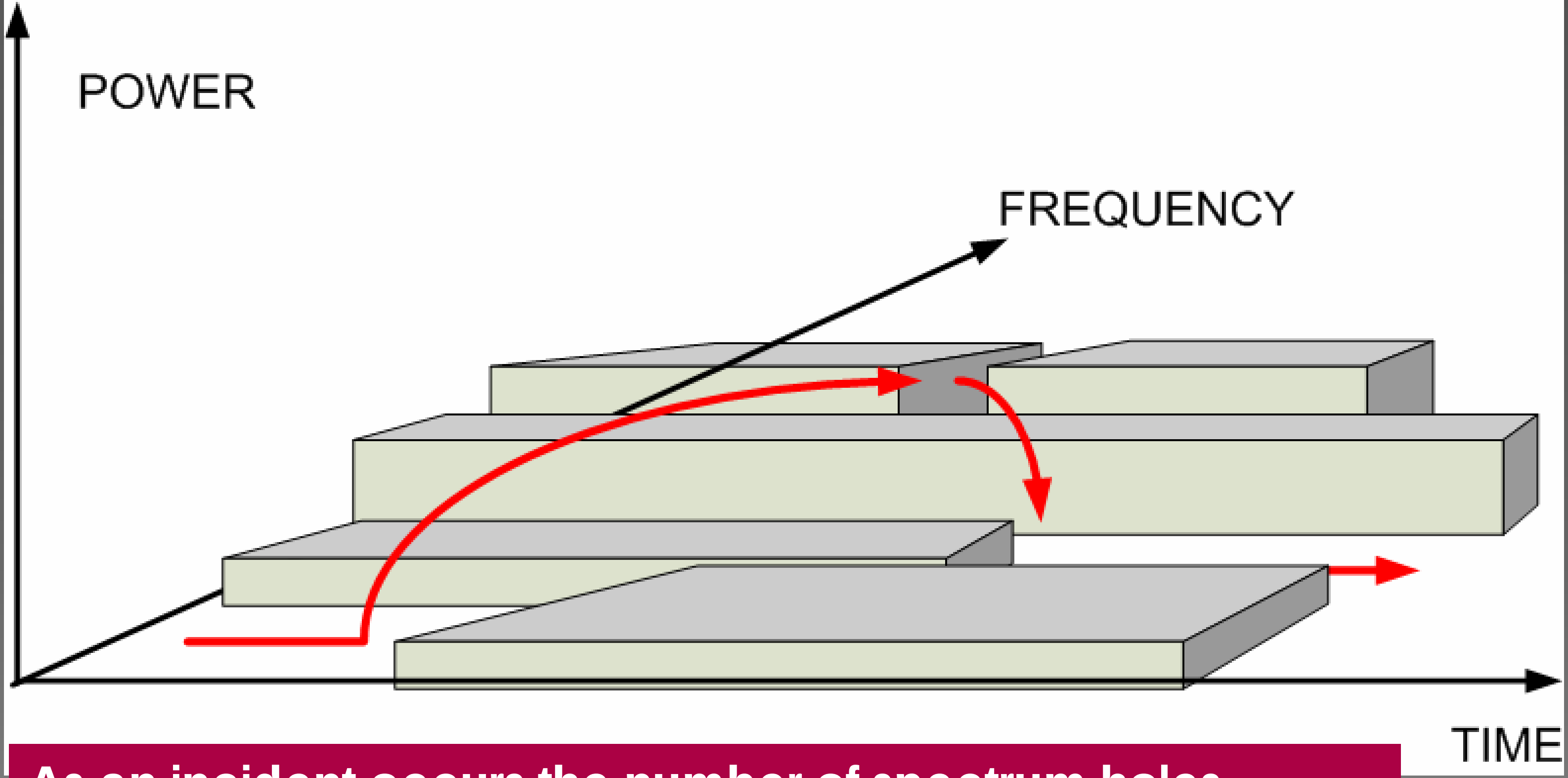
1. What is a cognitive radio?
2. Why do we need a cognitive radio?
3. Where do we place the intelligence?
4. How do we gain intelligence?
5. How does this apply to public safety?

Public Safety Design Requirements

Public safety is a unique application. Unique characteristics include:

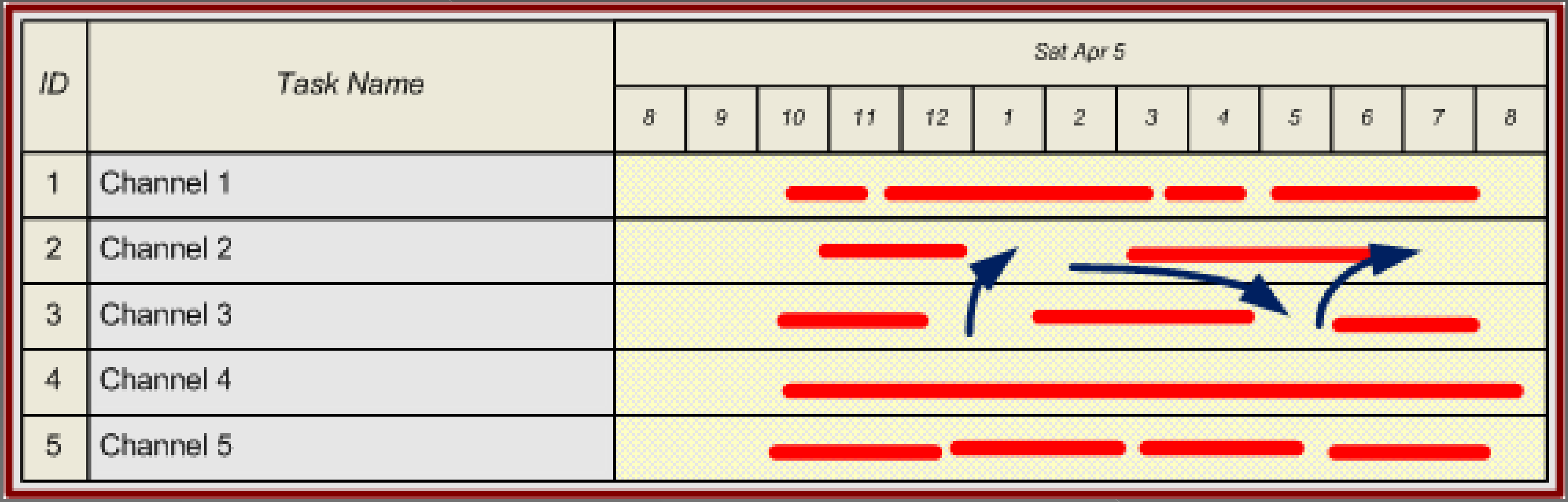
1. System loading and/or channel usage
2. Cross-functional teams
3. Varying levels of security (higher in the ISO stack)
4. Quality of service (QoS) requirements
5. Coverage requirements
6. Potential lack of infrastructure
7. NO $$s

Public Safety System Loading



As an incident occurs the number of spectrum holes disappear lowering the potential impact of a cognitive radio.

Public Safety Incident Channel Usage

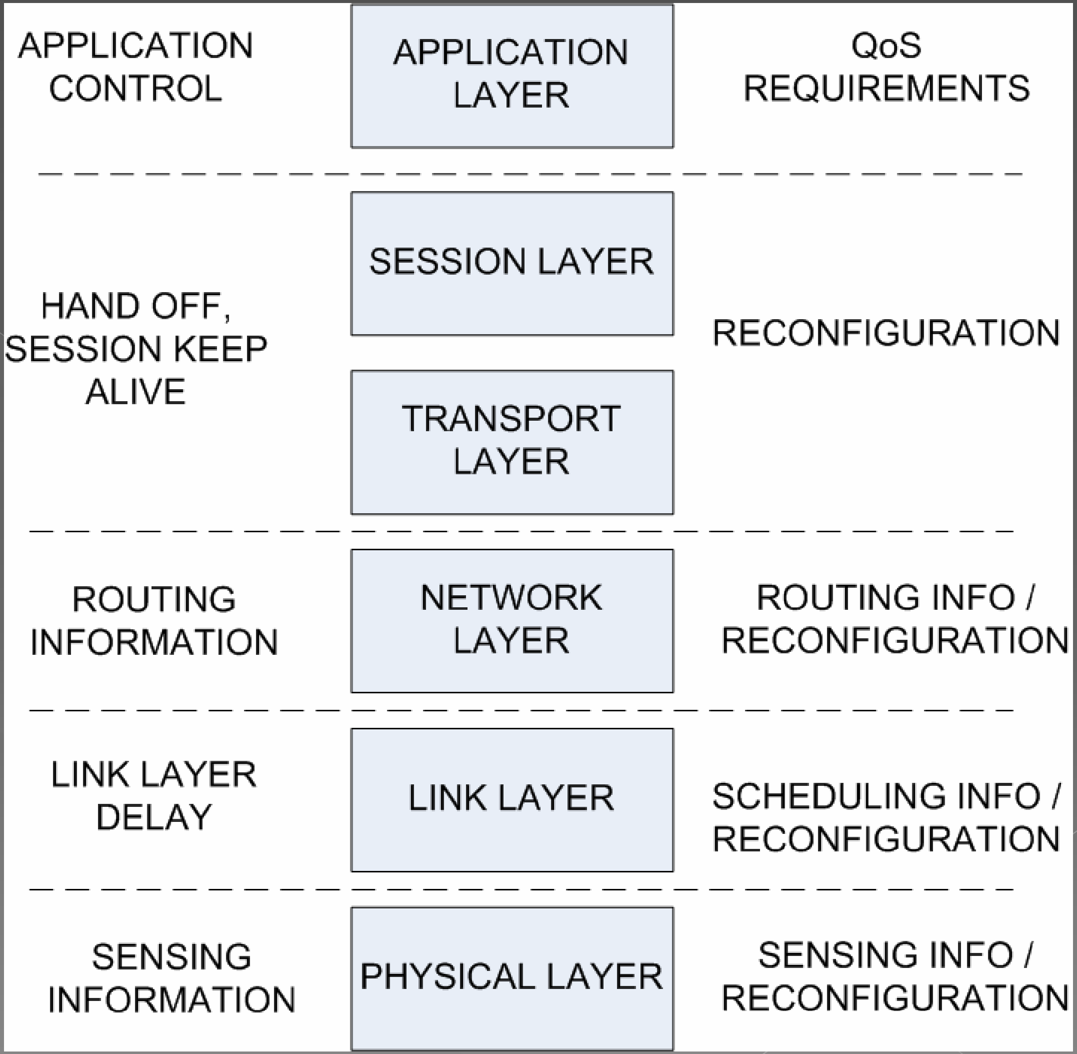


ID	Task Name
1	Channel 1
2	Channel 2
3	Channel 3
4	Channel 4
5	Channel 5

Due to channel usage, the cognitive radio must be able to accommodate wide areas of spectrum, multiple bands, or make up for decreasing channel availability through other methods to provide transparent mobility

Protocol Considerations

Cognitive radios will require development of new protocols to meet public safety requirements.



APPLICATION CONTROL	APPLICATION LAYER	QoS REQUIREMENTS
HAND OFF, SESSION KEEP ALIVE	SESSION LAYER	RECONFIGURATION
	TRANSPORT LAYER	
ROUTING INFORMATION	NETWORK LAYER	ROUTING INFO / RECONFIGURATION
LINK LAYER DELAY	LINK LAYER	SCHEDULING INFO / RECONFIGURATION
SENSING INFORMATION	PHYSICAL LAYER	SENSING INFO / RECONFIGURATION

6th Question

1. What is a cognitive radio?
2. Why do we need a cognitive radio?
3. Where do we place the intelligence?
4. How do we gain intelligence?
5. How does this apply to public safety?
6. Next steps?

Next Steps

Considerations:

1. Cognitive radios are years away for public safety
2. Unit cost will be a factor
3. Power requirements will be a factor
4. System risk due to complexity must be considered
5. Technology life cycle must be considered
6. The role of cognitive radios in incident response and ICS need to be considered
7. Spectrum value may require cognitive radios
8. Its never too late to begin standards development
9. Don’t forget software defined radios

QUESTIONS?